Changing Climate and Changing Agriculture

1.0 Introduction and Goals of the Assessment

1.1 Introduction

American agriculture is a system that has changed rapidly and continually at least since European colonization of the continent. All evidence is that agriculture will continue to change rapidly in the future. One of the forces to which future American agriculture will likely have to adapt to is changing climate, induced by the accumulation of greenhouse gases in the atmosphere. The impacts and adaptations that may occur in response to changing climate are the primary topics of this assessment. We also consider weather variability and its impact on agriculture focusing on some of implications for adapting to climate change.

Our report is part of a National Assessment effort aimed at evaluating the impacts of climate change and climate variability on the United States across its various regions and including sectors beyond agriculture. In this Chapter we begin by outlining the broad dimensions of the Agricultural Sector Assessment as part of the National Assessment. This discussion includes the purpose and goals of the assessment. We then provide a broad overview of the American agriculture, its past, current conditions, and trends that will take it into the future. We conclude this chapter with a report of the interests of agricultural stakeholders. These include views of those in the business of producing food and fiber and the related input and processing industries, those particularly concerned with the environmental attributes of agriculture, and those involved in public policy and program management in agriculture.

Within the agricultural community there is much interest in the impacts of *climate change mitigation policies* on agriculture. There are potential costs (higher energy prices and costs of controlling other greenhouse gases such as methane and N_2O) and opportunities (receiving payments for sequestering carbon in soils) for agriculture. Evaluating these costs and opportunities is not within the scope of this report or the National Assessment effort. Interested readers are referred to the report, "Economic Analysis of U.S. Agriculture and the Kyoto Protocol" prepared by the Office of the Chief Economist, Global Change Program Office of USDA with technical input from the Economic Research Service (http://www.usda.gov/oce/gcpo/gcponews.htm).

1.2 The Agriculture Sector Assessment and the National Assessment

1.2.1 The National Assessment of Climate Change and Climate Variability

The National Assessment is a joint activity of the federal, state, and local governments, and the private sector to understand the implications of climate change and climate variability for the nation. Periodic assessments of global change research and the implications of global change for the Nation were mandated by Congress when the US Global Change Research Program was authorized by the Global Change Research Act of 1990. The US Global Change Research Program has grown to a proposed $1.787 billion in the year 2000. Details on the program and links to many other climate change sites can be found at http://www.usgcrp.gov. The Federal government initiated the ongoing

National Assessment activity to fulfill, in part, the requirement of a periodic assessment of the Global Change Research Program. The initial phase of the Assessment will result in a synthesis report to be produced in early 2000. Details on the National Assessment beyond those provided here and links to other related sites can be found at http://www.nacc.usgcrp.gov.

The National Assessment includes regional assessment activities intended to make research results relevant and useful to the conditions, issues, and concerns as they vary across the country. Sector assessment activities are also incorporated and designed to integrate across issues that cannot be dealt with easily on a regional basis. These include topics such as inter-regional and international trade and competitiveness. In addition to the Agricultural Sector Assessment, the National Assessment also includes assessment activities for forestry, human health, coastal areas, and water resources. While not a comprehensive list of sectors and activities affected by climate variability and climate change, the sector assessment activities cover some of the sectors and systems most sensitive to climate.

The National Assessment also includes a synthesis activity designed to pull together the results from the regions and sectors to produce a summary report, scheduled for completion in early 2000. Region and sector assessments provide critical input to the synthesis activity. They will produce reports on varying schedules that provide detail of specific relevance to regional and sector stakeholders and researchers.

An important goal of the National Assessment is that it be participatory and seek to engage stakeholders and the public. This philosophy flows from the belief that applied science must be applicable to the needs of those who are intended to use it. It is far more likely that research will be applicable if the users and potential users are involved throughout the assessment process. In this spirit, the Agriculture Sector Assessment sought a Steering Committee, composed of stakeholders and potential users of the research to guide the agriculture sector assessment. The full report of the initial meeting of the Steering Committee and Sector Assessment Team is available at http://www.nacc.usgcrp.gov/sectors/agriculture/workshop-report.pdf. The Agricultural Sector Assessment has made an effort to closely coordinate with the regional assessment activities that have included a significant agricultural assessment to the extent the schedules of the efforts were compatible. Indeed, several members of the agricultural sector assessment team are responsible for agricultural assessment in various regional assessments. Similarly, efforts have been made to coordinate with other sector assessments. Where possible results from other sectors (for example, changes in water availability and their impact on irrigation water supplies) have been used as input into our evaluation of agriculture. And, as in the case of regions, the agricultural sector assessment team overlaps with other sector assessment teams (i.e. water and forests).

1.2.2 Purpose and Goals of the Assessment

In keeping with the purpose and goals of the National Assessment, the Agriculture Sector Assessment Report has three broad objectives:

1 To provide state of the art research results for the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). The Intergovernmental Panel

on Climate Change is the major international effort to periodically assess developments in climate change as guidance to international negotiations on climate change (see http://www/ipcc.ch).

2 To respond to the goals of the "Global Change Research Act of 1990." Section 106: Scientific Assessment, directs the US Global Change Research Program to, on a periodic basis, conduct an assessment that:

   a. integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
   b. analyzes the effects of "GLOBAL CHANGE" on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
   c. analyzes current trends in "GLOBAL CHANGE", both human-induced and natural, and projects major trends for the subsequent 25 to 100 years."

3 The Agriculture Sector Assessment should bring useful scientific results to decision-makers in agriculture with the aim of providing information for better decisions.

Closely related to the above objectives, the National Assessment has identified four questions that should be answered as part of the Assessment:

1. What are the key stresses and issues facing agriculture?
2. How will climate change and climate variability exacerbate or ameliorate current stresses?
3. What are the research priorities that are most important to fill knowledge gaps?
4. What coping options exist that can build resiliency into the system?

These objectives and questions guided the Agricultural Sector Assessment. To address them we met with agricultural stakeholders, reviewed relevant research and recent assessments, and conducted a program of modeling and research. Funding was by USDA. The US Department of Energy also provided significant funding to support the participation of the Pacific Northwest National Laboratory. The Farm Foundation and Economic Research Service of the USDA provided additional support for a stakeholder meeting.

Funding constraints required us to choose carefully new areas to investigate to advance the frontiers of our understanding where possible. In general we tried to build on past work rather than repeating the same exercises done earlier. In particular there have been several quite recent (last 4 years) assessments of climate change and agriculture that involved literature review. We summarize the findings of these and provide a more detailed discussion of our methods in Chapter 2. Stakeholders identified questions that were, however, much broader and more far-reaching than were covered in recent assessments (See Section 1.4). We focused our new research on some of these topics for which the research tools to conduct quantitative assessment were adequate. In many cases, however, answers to these questions would require forecasts and projection with accuracy beyond that we now have or the development of new assessment tools. The best we could do with regard to these topics was to identify them as open questions and

offer some brief observations of the possible implications of climate change. Doubtlessly, this shortcoming will leave readers with these interests less than fully satisfied.

Our analysis is a fairly comprehensive treatment of the country with details on individual crops and regions. Given our limitations on funding and resources the level of detail is, however, certainly inadequate for state and local decision-makers. We see the job of interpreting and deepening the analysis as that of the regional assessment efforts that are composed of researchers with a much firmer understanding of the local context. This is particularly crucial for understanding coping strategies relevant to farmers whose conditions vary. In this regard, we follow a tradition in agricultural research and extension that relies on state and county level experts to provide guidance directly relevant to local farmers.

1.3 Agriculture: Past, Present, Future

Our only guide to the future is what we know about the current state of agriculture and the trends and responses we have evaluated from the recent past. Part of this knowledge are trends in development and adoption of state-of-the-art technologies. By understanding the technological forefront we might hope to see a decade or two ahead but such assessment is still based on current knowledge and historical experience with adopting new technology. In this section, we do not attempt to comprehensively describe agriculture and certainly do not offer precise predictions for US agriculture for the next 100 years. The Economic Research Service (ERS) of the USDA regularly surveys and reports on the current status of American agriculture, its relationship to the rest of the world, its use of natural resources and the environment, and the health and nutritional status of the US population. Myriad data, reports, and assessments conducted by ERS are available at http://www.econ.ag.gov. The goal here is to provide a broad-brush outline of the American agriculture system, what it has learned from the past, where it is now, and where it may be in the next century.

Our focus in this review is to identify some of the important connections with weather and climate. Any effort to cope with climate change and climate variability in the future will grow out of and react to the perception of success or failure of past efforts to manage agriculture. As impossible of a task as it is to summarize American agriculture, something of a description is needed to provide a context for studies of the impact of climate change and variability.

1.3.1 One-Hundred Years of Change

American agriculture has undergone vast changes over the past century. In 1900, 60 percent of the population lived in rural areas, there were 6.4 million farms and the average farm size was 132 acres. By 1990 only 25 percent of the population lived in

rural areas, there were 2 million farms and the average farm was 435 acres.[1] Even in 1900, however, American agriculture was an export industry. Cotton, tobacco, and wheat crops were exported to Europe. And, as vast as the country seemed at the time, some predicted that the bounty would be exhausted soon by an ever-growing population. Sir William Crookes, writing in 1900, concluded that "it is almost certain that within a generation the ever increasing population of the United States will consume all the wheat grown within its borders, and will be driven to import, and like ourselves, will scramble for the lion's share of the wheat crop of the world" (as quoted in Dalrymple, 1980). Indeed, the early 1900's produced some of the most prosperous times for farming. The years of 1912-1913 were later seen as the last point where farmers were paid a "fair" price for farm products. Through a series of economic downturns and even economic booms, agricultural prices seemed to go mainly down. Whereas the American economy boomed after World War II, agriculture seemed mired in low prices. Economic development in rural areas lagged behind that in urban areas.

Oddly (for those who had looked ahead to see food so scarce that hunger and famine would spread), even as more and more farmers left the farm, more and more food was produced and commodity prices continued to fall. Evidence of this worldwide trend since the 1950's are the falling real prices for food commodities (fig. 1) and steadily increasing agricultural output. Indices of real prices for all food products and for cereals both fell over 60 percent from around 1950 to the early 1990's.[2] Worldwide food production growth over the past three decades has also been relatively consistent, increasing by 2.7% per annum during the 1960s, 2.8% during the 1970s, and 2.1% during the 1980s.

INSERT FIGURE 1

How did this happen? In the US, the great dams and water projects of the West made the deserts bloom. New and more powerful machinery made it possible for those remaining on the farm to till hundreds of acres instead of tens of acres. Starting in mid-century crop breeding began producing a constant supply of new varieties that have increased yields exponentially for more than 50 years. Since 1939 annual exponential rates of growth in yield for corn, potatoes and sorghum have been on the order of 2.5-3.0%; for rice, wheat, barley, and cotton the increase has been on the order 1.8-2.2%; for

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1 Data on the rural population are from the Census Bureau (http://www.census.gov/population/censusdata/urpop0090.txt). Data on farmland are from the USDA National Agricultural Statistical Service and based on Census data (1999 Agricultural Statistics available at http://www.usda.gov/nass/) and computed from tables 9.7 and 9.8. Definitions of farms and thus land in farms and number of farms has varied. Other tables give slightly different estimates.

2 The real price decline for total food was 63% and for cereals was 62% using as a base the 5 year average for 1948 through 1952 as compared with the 1992-1996 period. Five year averages were used to minimize the impact of choice of base year which can be substantial given the volatility of commodity prices.

soybean, oats, sunflower, and flaxseed the increase has been on the order of 1.0-1.25% (Reilly and Fuglie, 1998). Improved varieties that were the basis for these increases required (or were able to take advantage of) high levels of nutrients, supplied by cheap inorganic fertilizers. Inorganic fertilizers were part of the chemical revolution that also brought new ways to control weeds, insects, and diseases in crops. Livestock also saw improved productivity through breeding, better veterinary products, improved farm management practices, and increasing mechanization. Agricultural economists, observing these forces in the 1950's, termed technical change in agriculture the "technology treadmill." In this interpretation, farmers must adopt the new cost-saving and yield-enhancing technologies just to stay even. Those that failed to keep up with technology would be run off the treadmill into an abyss of economic losses as neighbors, the farmers in the next state, or competitors around the world kept running. Improved shipping and transportation reduced ever further any edge a farmer might have in supplying the local markets.

Concern about farm income and prices coming out of the Great Depression of the 1930's led to long-enduring farm programs. Variability, induced by weather, was one justification for these massive programs. The idea was that the government would buy up commodities when harvests were big, keeping prices up, and sell these stocks when there were crop failures thereby preventing prices from sky-rocketing. In this hopeful view, both farmers and consumers would benefit from stable prices. After nearly a half-century of these programs, however, analysts still argue whether government intervention may have, instead, increased variability. Along with the desire to even out prices was the desire to assure a reasonable income for farmers. Thus, the halcyon days of 1912-13 became the benchmark for parity prices, prices (or some proportion of which) farm programs would seek to assure farmers. High prices brought more output, however, and ever increasing surpluses, that when put on the market depressed prices. In trying to fight these market forces, farm programs became a complex combination of foreign (and domestic) food aid, acreage reduction programs, commodity stockpiles, and an array of payment mechanisms that were somehow meant to provide income support without bringing on gluts of production. Farm legislation in 1996, termed the FAIR act, was intended to transition US agriculture over a period of 7 years toward full reliance on markets, ending once and for all, this system of incentives and counter-incentives.

Dating to the Morrill Act of 1862, which granted States and US territories scrip to land which they could sell to develop colleges that would offer practical instruction in agriculture and the mechanical arts, a nationwide system of agricultural experiment stations have turned out ever-higher yielding varieties, farm management assistance, and improved livestock. Publicly funded research, freely provided to farmers, was no doubt a major force behind the yield improvements identified above. The role of public funding has changed as the private sector has increased research and development, taking over much of the applied and product development research, and using intellectual property rights protection to recoup the investment. See, Fuglie, et al., 1995 (http://www.econ.ag.gov/epubs/pdf/aer735) for a comprehensive analysis of public and private research in agriculture. Productivity growth measured as the total cost of inputs has been high since at least the 1950s, averaging better than 1.9% per year (Ahearn, et al., 1999; available at http://www.econ.ag.gov/epubs/pdf/aib740/). This has allowed output to double over the period while input use remained essentially unchanged.

Changing regional competitiveness has also been a feature of changing agriculture. The changing competitiveness and fortunes of different regions cannot be traced to a single factor. The opening of canals, building of railroads, construction of large water projects, shifting population, changing technology, the introduction of new pests, and either resource degradation or opening of new more productive areas, and environmental considerations have all come into play. Woven into this was the nature of the people who took up farming in different regions, or instead chose to move on or out rather than adapt. Milk production shifted from New York and Pennsylvania to Wisconsin and then to California and Florida. It has left behind fading red barns and reforested hills. Cotton shifted from the South to southwest and west as pests, depleted soils, and irrigation water changed fortunes of different regions. Most fruit and vegetable moved from being locally produced and only seasonally available to being available in supermarkets year-round, with worldwide suppliers. But even processed vegetable production shifted. Cheap and widely available transport gradually increased the regional specialization of cropping and livestock production to those areas that were particularly favorable for a particular crop or were particular unfavorable for everything else. As competitiveness demanded ever greater management, farmers could fair best if they focused on one or a few complementary crops that did well under the climatic and resource conditions they faced. Both they and the input suppliers and product processors could reap economies of scale from large and regionally concentrated production.

One way of examining how production has shifted is to plot the geographical center of crop production. Figures 1.2 to 1.4 provide such a plot for corn, wheat, and soybeans, constructed for the agricultural sector assessment and described more fully in Hollinger (2000). These illustrate shifts of 50 to 100 miles in the geographical center of production for these crops in as little as 50 years. The cause of these historical shifts is almost certainly not related to climate change. The proximate cause of such shifts, one region gaining a competitive advantage over others, whether due to climate, technology, or some resource change will set in place many of the same types of social and economic adjustments with people moving from the less prosperous regions to the more prosperous region. Most of this adjustment is likely to occur not near the center of production but rather at the boundaries where production of a crop is expanding, requiring land to be converted and perhaps new infrastructure to be developed, or where production is contracting, leading to the abandonment of land for agricultural purposes.

Throughout the century agriculture has also faced weather. Droughts, cold, late and early frosts, extreme heat, storms affect some area of US agriculture in almost any given year. At times they are widespread or catastrophic enough or affect a constituency such that the weather and its impact on agriculture briefly enters the media and is broadcast to the 99 percent of Americans who are not farmers. For the most part, however, whatever disaster befalls the farmer, the American consumer is little affected. The decision of whether to leave a 10, 15, or 20 percent tip at the restaurant probably has more economic consequences for many Americans than any impact they will see from adverse weather effects on farm production. A big drought or widespread weather catastrophe might increase retail food prices by three to four percent; Americans spend more than one-half their food dollars eating out. The nature of agricultural demand (highly inelastic in economic terms) means that a good widespread drought can be the best thing to happen to the bottom line of the farm economy, raising prices more than

supply is cutback and thus increasing farm revenue. On the other hand, a localized drought such as occurred in the Mid-Atlantic in 1999 combined with near-ideal growing conditions throughout large growing regions in the Mid-West can lead to financial losses for most farmers. Lower prices due to overall good production can mean that even farmers that experienced good growing conditions and high yields do not cover costs. Those that suffer yield loss due to drought face low prices combined with reduced production.

Weather is so central a feature to farming that most of the techniques used in farming, agribusiness, and the food industry somehow reflect a desire to overcome weather. It is not stretching the facts to observe that there is no such thing as a "normal" year. A year characterized by 30-year means for all months of the growing season and showing an "average" pattern of extremes would be truly abnormal. Conquering variability is manifest in nearly every dimension of farm management. Included are hard technologies such as crop drying, irrigation, drainage and tiling, storage, shading and cooling for livestock; selection and breeding of livestock and crops that are hardy or hardier under a wider range of climatic conditions; financial and farm management such as financial savings, borrowing, crop insurance, diversified production strategies, and off-farm income; market instruments such as forward markets and contract production that shifts and pools risk; prediction and outlook on weather and economic conditions; and finally government policy such as disaster assistance, farm programs, and government involvement in the insurance markets.

1.3.2 At the Brink of a New Century

Agriculture production is very diverse. This diversity bespeaks of an industry undergoing rapid change. We excerpt below a verbatim summary of highlights from the most recent Family Farm Report produced each year by the Economic Research Service of USDA under Congressional mandate. The summary and details on ordering the report are at http://www.econ.ag.gov/epubs/htmlsum/aib735.htm. The report finds that

- More than 2 million U.S. farms produced agricultural commodities that generated an average of $74,000 in gross value of sales per farm in 1994. Still, 73 percent of farms had gross value of sales under $50,000 (noncommercial farms), although they accounted for just 11 percent of total U.S. farm sales.
- Gross cash farm income (adjusted to exclude the share of production accruing to landlords and contractors) averaged near $69,000. However, gross cash farm income for the Nation's largest farms (sales $1 million or more) averaged almost $2 million, so that less than 1 percent of farms accounted for 23 percent of gross cash farm income. Commodity sales accounted for 84 percent of total gross cash farm income, with government payments adding 5 percent and other farm income 11 percent.
- Acreage per farm, which has tripled over the last six decades, averaged 448 acres operated in 1994, but half of all farms were under 180 acres. Livestock farms producing some combination of beef cattle, hogs, and sheep accounted for the largest share of farms grouped by farm type. Even

though these farms had larger acreage than the U.S. average, they had lower average gross cash farm income and gross value of sales.

- Half of all farms cash-rented or share-rented some or all of the land they operated in 1994. Farm operators who owned all the land they operated but had a rental arrangement for machinery, buildings, or livestock (5 percent of full owners) had income and sales five times as high as full owners who rented nothing.
- More than 90 percent of farm businesses were legally organized as individual operations, while 6 percent of farms were partnerships and 4 percent were corporations (most of which were family-owned).
- Farms organized as individual operations averaged more than $50,000 in gross value of sales and had farm assets that averaged more than $350,000.
- While 13 percent of all farm operators reported having some contractual arrangement for production and/or marketing of farm commodities, farms with marketing contracts outnumbered farms with production contracts by more than 4 to 1.
- Use of contracting arrangements varied by such farm characteristics as sales class and type of production. For example, more than 60 percent of poultry farms had production contracts.
- Net cash farm income averaged $11,696 for farms nationwide, but ranged from negative for farms with sales under $50,000 to over $380,000 for farms with sales of $1 million or more.
- Farm assets generally increased with sales class, but even farms with sales under $50,000 had farm assets averaging more than $250,000. Farms with gross value of sales of $1 million or more used assets valued at over $3 million to generate $2 million in gross cash income. These large farms also had the highest debt-to-asset ratio (0.25).
- In 1994, 61 percent of farms were in a favorable financial position with a low debt-to-asset ratio (0.40 or less) and positive net farm income. Another 34 percent of farms had a low debt-to-asset ratio but were unable to generate enough income to offset expenses, so net farm income was negative, putting them in the marginal income category. Most of these operations were noncommercial farms.
- Only 4 percent of farms were in a vulnerable financial position where a high debt-to-asset ratio (0.40 or more) and negative net farm income threatened long-term survival of the business.
- More than a third of farms received income from government payments, averaging $9,306 per receiving farm. Almost two-thirds of commercial farms (gross value of sales $50,000 or more) compared with one-fourth of noncommercial farms received government payments. However, government payments accounted for less than 3 percent of gross cash farm income for commercial farms compared with 41 percent for noncommercial farms.
- Over 40 percent of the Nation's farm operators reported farming or ranching as their principal occupation. Their farms accounted for more

than 80 percent of gross cash farm income and gross value of sales. Households of operators with a principal occupation of farming had average total household income that was about 85 percent of the U.S. average. About a third of total income for these households came from earnings from farming activities, and two-thirds from off-farm sources.

- Operators under 35 years old accounted for 9 percent of all operators, while operators 65 years old and over accounted for 24 percent. The youngest operators, however, generated their proportionate share of total U.S. gross cash farm income and gross value of sales based on number of farms, while the oldest group generated about half their proportionate share.
- About 13 percent of all farm operators used electronic information services to get farm business information. Use of this new technology increased with farm size and operator educational attainment level (20 percent of operators who completed college compared with 10 percent of those who completed only high school).
- More than 60 percent of farm operators ranked getting out of debt and improving crop yield or livestock production as very important business goals. Commercial farm operators ranked these goals higher than noncommercial farm operators.
- Mean household income from all sources for farm operator households was near the U.S. average. On average, 90 percent of total operator household income came from off-farm sources. For almost half of farm households, earnings from farming activities (farm self-employment income plus other farm-related earnings) were negative, but total household income was positive because off-farm income exceeded the loss.
- As farm sales increased, household dependence on earnings from farming activities increased and household income relative to the U.S. average increased.
- Operator households associated with farms that had a gross value of sales of $500,000 or more had average household income 3.5 times the U.S. average, and earnings from farming activities accounted for 75 percent of total operator household income.
- Noncommercial farm operators worked half their annual working hours on the farm, and their spouses worked about one-fourth of their working hours on the farm.
- Commercial farm operators worked 88 percent of their total work hours on the farm, while spouses averaged almost half their total work hours on the farm.
- Rankings of eight selected measures of farm business success showed that having farm income sufficient to support the household was more important to operators reporting their principal occupation as farming.
- More than half of farm operators reported passing the operation on to the next generation as very important.

The remarkable aspect of this summary is the diversity. Indeed, the enterprise of farming appears to have divided into at least several broad categories. The bulk of commodities are produced on large commercial farms with large revenues, whose operators rely principally on the farm as a source of income, and who earn a family income above the average of the US household. A second group of farm operators run small farms where net income from the farm is very small or negative with the income of the household determined by the off-farm earnings of the household members. Another group of farmers are those who are near retirement or in semi-retirement. This group typically owns outright all the land they operate or, in fact, may rent most of their land or have it enrolled in a long-term easement program like the Conservation Reserve Program that pays farmers of highly erodible land to maintain permanent cover on the land. A fourth categories are those in the middle.

The middle-sized group is most vulnerable to the century-long trend toward larger farms. Farmers in this group are most likely struggling to earn an income from the farm operation and supplementing household income with off-farm employment, working for the day when the family can survive on farm income alone. They face difficulty in affording expensive new technologies such as precision-farming that involve on-board computer monitoring guided by global positioning systems (GPS). As profit margins tighten increase, the scale of operation must necessarily grow if the main occupation is to remain the main source of family income. One alternative for this group is to produce under contract with processors. Already widespread in the poultry and hog industries, the processor bears more of the risk and provides specific guidelines for production. It represents a major cultural change for many farmers who value the independent life that farming has traditionally represented.

The more recent trend that has emerged in the last decade is that the smallest farm categories have shown increasing numbers. The reasons for this trend are highly diverse as well. People returning to farm, supplementing farm income with off-farm employment and perhaps no intention of fully supporting themselves through farming are one group. Others have found niche and local markets where the profit margins are higher than for bulk commodities. Operators have found success with everything from organic foods herbs sold to high-end restaurants, Christmas trees, selling to local farmers markets, or inviting consumers to pick-their-own, perhaps combined with some form of entertainment for the urban dweller seeking a farm-experience.

The main lesson for climate change is that it is unlikely to change this dynamic in any fundamental way. The regional effects of climate change may vary considerably as we detail in later chapters. It is likely that an increasing percentage of bulk commodities will be produced on the largest farms. The middle-sized farms will continue to be squeezed if they must compete in bulk commodity production. Niche producers for local markets can be successful if the products are cleverly chosen, the enterprises are well-run, and the products deftly marketed. Success will, however, inevitably invite competition. If climate change is somehow beneficial to a region it may ease the pressure a bit and allow breathing space. If climate change has adverse consequences for the region, it may tighten the grip on the most vulnerable producers. Agriculture is, however, a highly variable enterprise with, relative to the industrial sector, relatively low barriers to entry. Hence, any evidence of increased profitability will tend to draw in more producers, bid up land prices, and keep the profit margin tight. So even if climate change

is somehow beneficial, it is unlikely to manifest itself as widely perceived windfall profits. Likewise if climate change is adverse, the gradual change is unlikely to be perceived as windfall losses. In both cases, downturns in commodity prices will continue to take out the vulnerable farmers and upturns will encourage production expansion.

1.3.3 Forces Shaping the Future

A few broad forces will shape the future for American agriculture over the next few decades. These are:

- Changing Technology. Biotechnology and precision agriculture will likely revolutionize agriculture over the next few decades as mechanization, chemicals, and plant breeding revolutionized agriculture over the past century. Biotechnology offers great potential to improve adaptability, develop resistance to heat and drought, and change the maturation schedule of crops. Biotechnology also will give rise to entirely new streams of products and will allow the interchange of characteristics among crops. Precision farming, the incorporation of information technology (e.g. computers and satellite technology) in agriculture, will improve farmers' ability to manage resources and to adapt more rapidly to changing conditions.

- Global food production and the global market place. Ever-greater linkages are the rule among suppliers around the world. These links are developing in response to the need to assure a regular and diverse product supply to consumers. Meat consumption is likely to increase in poorer nations as their wealth increases and this will place a greater pressure on resources. Climate change could exacerbate these resource problems. Trade policy, trade disputes (as over genetically modified organisms), and the development of intellectual property rights (or not) across the world could have strong effects on how international agriculture and the pattern of trade develops.

- Industrialization of agriculture. The ever-faster flow of information and the development of cropping systems that can be applied across the world will transcend national boundaries. Market forces are encouraging various forms of vertical integration among producers, processors, and suppliers, in part driven to produce uniform product and assure supply despite local variation induced by weather or other events.

- Environmental performance. Environmental performance of agriculture is likely to be a growing public concern in the future and will require changes in production practices. Significant environmental and resource concerns related to agriculture include water quality degradation due to soil erosion, nutrient loading, pesticide contamination, and irrigation-related environmental problems; land subsidence due to aquifer drawdown; degraded freshwater ecosystem habitats due to irrigation demand for water; coastal water degradation due to run-off and erosion; water quality and odor problems

related to livestock waste and confined livestock operations; pesticides and food safety; biodiversity impacts from landscape change (in terms of both habitat and germplasm); air quality, particularly related to particulate emissions; and landscape protection. Tropospheric ozone is increasingly recognized as an industrial/urban pollutant that negatively affects crops. Agricultural use of land can also provide open space, habitat for many species, and, with proper management, a sink for carbon and these positive environmental aspects are likely to be increasingly valued.

In the past, it has been possible to summarize the forces shaping agriculture as a competition between increased demand for food driven by a larger and higher income population and increased supply driven by new technology. Over the period of a few decades a tenth of a percent difference in exponential growth rates of population and technological progress can make the difference between ever-falling or ever-rising prices. The ability to predict these rates of change with the degree of accuracy necessary to resolve the difference does not exist. Most likely, the rate of technical progress responds to demand pressure as well as the opportunities opened up by improvements in basic research. As historical periods of rapid commodity price rises indicate, agriculture supply has tremendous ability to respond over the course of a few years. The best bet is thus likely that commodity prices will continue their long-run decline as several major global forecasting efforts have suggested and as reviewed by Reilly and Schimmelpfennig (1999). The specific nature of technical change and what it means for different regions and farming systems remains elusive to predict. Over the next few decades, there are not obvious biological limits on yields that would prevent continued increase (Reilly and Fuglie, 1998). In the longer, term far greater changes are possible. Industrialization of agriculture could mean raw biomass is processed into livestock feed and processed food products using biotechnology generated microbial organisms, greatly reducing the need for conventional crop production as we now recognize it. As we try to look forward 50 and 100 years, it is not clear whether the crops that will be grown then will resemble the crops grown today. While such changes are possible with new technology, we must also look back to the fact that civilizations have relied on the major grain crops for centuries and, and breaking from this would represent a epochal change in human history. It is never-the-less worth stretching our thinking if we are to conceive of what the American agriculture could look like in the year 2100.

Farm policy will affect work around the edge of these broad forces but in most respects it is unlikely to alter much the inevitable push of technology and fundamental market forces. This, if anything, is the lesson of farm policy over the second half of the twentieth century. Well-meaning policies designed to improve the income of farmers created incentives to produce that overwhelmed the market and drove prices down, filling public granaries. Attempts to hold prices up in the face of technology that reduced costs and increased production also generated surpluses. Thus, ultimately, the Federal programs were forced to liquidate stocks and lower the target price they hoped to maintain.

We cannot easily predict how policy will try to blunt the adjustments and dislocations that these forces will bring. On the near-term agenda agricultural policy is evaluating the effects of the FAIR act of 1996. The basic background was that the FAIR

act of 1996, passed with much fanfare, and intended to bring an end to an era of farm programs, is being reconsidered. Reconsideration of FAIR is likely because low prices in 1998 caused new financial stresses for agriculture and most see little prospect that prices will improve in the next few years. Given this background the major issues likely to come up in Congress over the next few years are:

- Will Congress revisit the 1996 Farm Bill to strengthen the safety net for farmers? It is likely that the fundamental shape of agriculture payments will continue? General observations by many in the agricultural policy community include:
  1. Assistance for economic disasters needs to be thought through.
  2. There is a sense that planting flexibility in FAIR worked and will be retained.
  3. There is an interest in improving crop insurance, but there are widely different ideas about what "improved" means.
  4. A sense that the shift away from counter-cyclical program payments was not well thought out by Congress in the 1996 bill.
  5. Federal support for agriculture will continue. Decoupling payments, the underlying approach in FAIR, was better in theory than in practice.
  6. Some unresolved questions include: Will payments be linked to environmental performance in 2002 farm legislation? What happened in the hog price collapse that caused so much stress in 1998/99? Were integrated contractors responsible? Is this a sign of more fundamental issues with regard to the structure of agriculture?
- In terms of international trade, the US will likely continue to seek further reductions in barriers to trade within the World Trade Organization. Specific issues will be state trading and trade in genetically-modified organisms. A problem facing further trade barrier reduction is that it is increasingly difficult to convince farmers that freer trade is good for them.
- Environmental pressures as they relate to agriculture are likely to become more important in the future.

These policy directions take us only at most a few years into the future and are subject to rapid change. They do, however, provide insight into the underlying concerns of the policy community that are likely to endure, as these concerns are not that different than those that have driven farm policy for several decades.

1.4 Stakeholder Interests

The Agriculture Sector Assessment developed a Steering Committee to provide input on the interests of the many and varied stakeholders in agriculture. Included among this group were small farmers, representatives from agribusiness, members of the agricultural research community, representatives from environmental groups, staff members of Congress, and those involved in implementing policy in the Federal and State governments. The full list of the Steering committee is contained in Appendix A. A full report of the first workshop is available at http://www.nacc.usgcrp.gov/sectors/agriculture/workshop-report.pdf.

The comments received from stakeholders could be summarized into nine broad issues. These were:

1. Agriculture is diverse. We must speak to the diverse elements that exist. Different concerns require that the assessment activity take different cuts on agriculture.
2. Agriculture is changing rapidly—biotechnology, computers, GPS, information technology, and the changing structure of production have collectively altered the sector. It is becoming an ever more highly-specialized, technology-driven enterprise and this means that farmers need a high level of training to operate successfully.
3. The assessment needs to be more integrated than previous efforts. Inter-related issues such as water, pests, land use, and ozone levels must all be dealt with effectively.
4. Variability is a big concern. It wreaks havoc on farmers.
5. Environmental links are unexplored but could be very important—opportunities for win-win solutions exist and should be further investigated.
6. The policy environment will be affected by climate change and will affect the ability of agriculture to adapt.
7. Think heavily about the structure of the assessment—learn from past efforts.
8. Worry about the accuracy of scenarios and analyses and where the errors are.
9. The assessment will be useful if we identify the range and breadth of issues (potential surprises) even if we cannot quantify all of these.

Stakeholders also had quite specific questions they hoped the assessment could tackle. The 16 questions below reflected the observations of Robert White from the legislative staff of Senator Richard Lugar, toward the end of the Stakeholder meeting held in January 1999.

1. How will crops and livestock be affected? The assessment should consider not only the ability to genetically alter crops and livestock in response, but also the effects of diseases and pests.
2. How will growing degree days change? Will the distribution of the current patterns change?
3. Will climate change result in changes in competition for land? How? What will the future baseline competition look like if climate changes?
4. Consider changes in the structure of agriculture—how will climate change affect operations? Will it make it harder or easier to get into agriculture?
5. How will international competitiveness be affected?
6. Consider changes in variability and also the predictability of both weather and climate. Can we predict better—remember cash is on the line for farmers if they act on predictions.
7. Consider direct and indirect effects—the interplay of water and nutrients—especially as they impact water availability and water quality.
8. How will climate change affect the environment via agriculture and will it affect the structure of natural resource management?
9. Where will the regions that gain competitive advantage be?
10. What will be the impacts on transportation, ports, lock and dam structures? They are currently in bad shape. Where should we build or abandon?

11. Where will processing plants exist? Do they need to co-locate with production? What if production shifts?
12. What about risk management strategies in terms of agriculture credit services? What will agriculture creditors demand as proof of ability to repay loans of farmers if production is much more variable?
13. How will federal, state, and local policymaking be affected? For example, the local tax base is dependent on property values—how will this tax base change? How will this affect school systems through tax base erosion and/or a declining population? Will there be a return to price supports at a federal level? How important or necessary are current federal policies with respect to risk? Will there be more regulations at the state, federal, or international levels and what might their impact be?
14. What will be the effect on the labor supply for agriculture? Labor is already tight in this sector.
15. Will there be adequate funding for research? What research should be funded?
16. Where will the new customers be so that better marketing strategies can be designed?

It was with this guidance that we undertook the research described in the following chapters. It was not possible to address all these questions with quantitative analysis but we have tried to provide information and discussion of the main topics.

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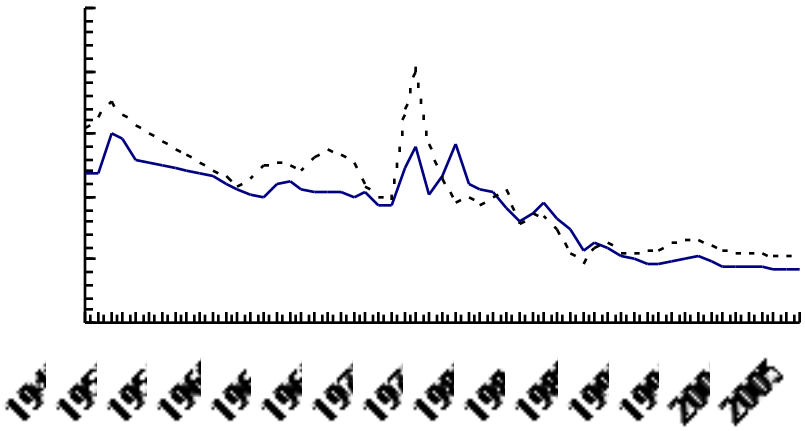
Figure 1.1: Index of World Food Prices, 1960 = 100. Dashed line, cereals; Solid line, all food commodities.



Source: Reilly and Schimmelpfennig, 1999.

Figure 1.2. Movement of the geographical center of US corn production, 1874-1992, production weighted.

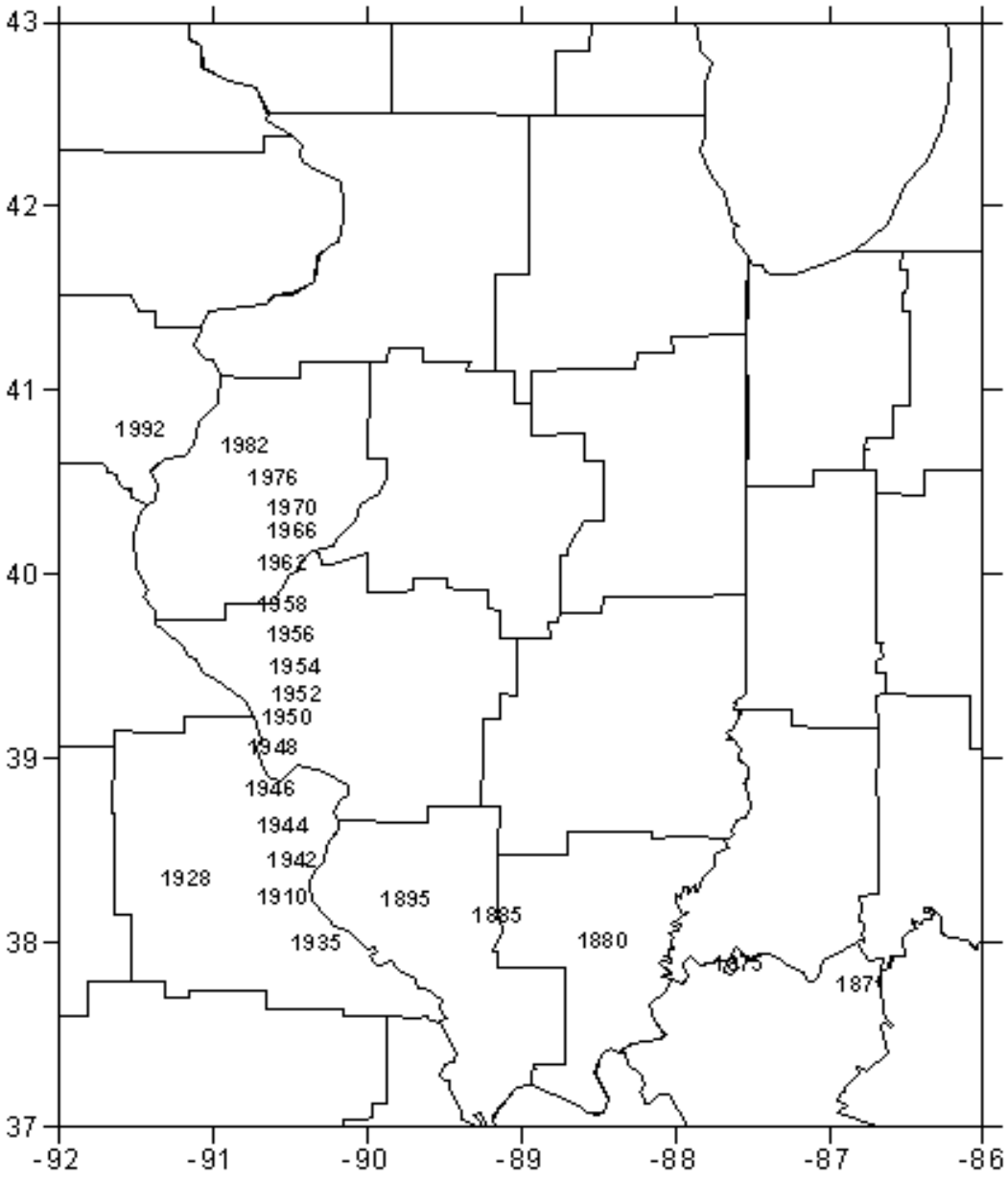


Figure 1.3 Movement of the Center of Wheat Production, 1871-1990 (weighted by production

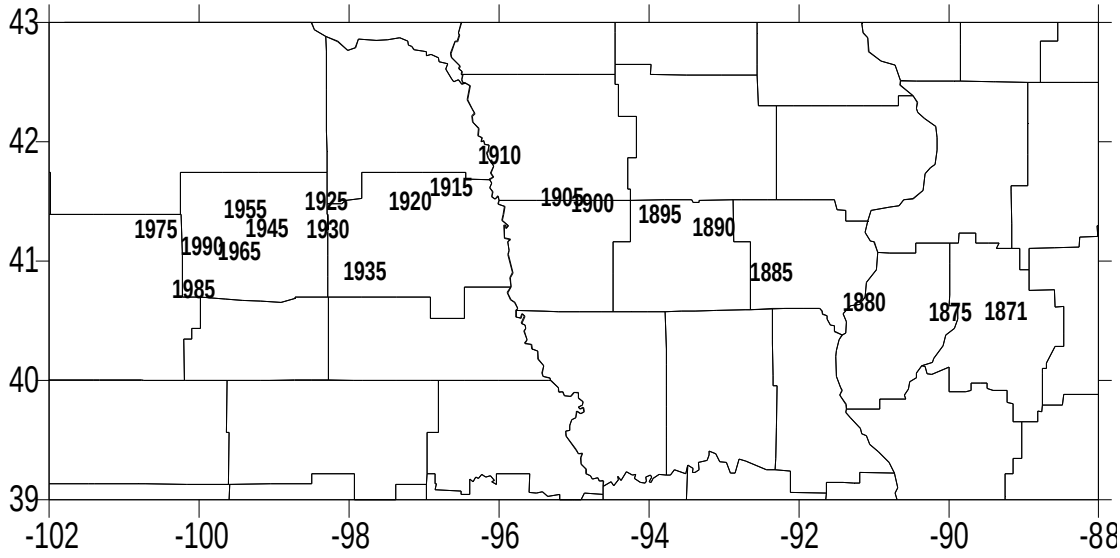


Figure 1.4 Movement of the Center of Soybean Production, 1930-1990, production weighted.